



## An Argument and Plan for Promoting the Teaching and Learning of Neglected Tropical Diseases

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**Neglected tropical diseases constitute a significant public health burden, affecting over one billion people globally, yet this group of diseases is underrepresented in the appropriation of both monetary and intellectual capital for developing improved therapies and public health campaigns. The topic of neglected tropical diseases has been similarly marginalized in the biology classrooms of our nation's high schools and colleges, despite offering an opportunity to teach and learn about a diverse area of microbiology with far-reaching public health, social, and economic implications. Discussed herein is an argument for increasing the representation of neglected tropical diseases in microbiology education as a means to generate increased interest in these diseases among the generation of future researchers and policy-makers, and to promote interdisciplinary learning, civic engagement, and critical thinking.**

### INTRODUCTION

Neglected tropical diseases (NTDs) is an umbrella term used to describe infectious diseases that primarily affect low-income populations in tropical regions and are often widespread, chronic, and debilitating. Although the number of diseases that are officially recognized as NTDs by various public health authorities ranges from less than 10 to over 40, the list of 17 diseases currently classified as NTDs by the World Health Organization (WHO) is widely accepted as accurate and comprehensive (20). Of these 17 diseases, four are caused by bacterial pathogens (Buruli ulcer, leprosy, trachoma, and Yaws), three are caused by protozoan parasites (Chagas disease, human African trypanosomiasis and leishmaniasis), two are viral (Dengue and rabies), and the other eight are caused by various species of parasitic worms (20). The most recent data available indicating the estimated number of cases of each NTD are listed in Table 1.

NTDs exert an immensely deleterious effect on the public health and economies of much of the developing world. Yet, by definition, NTDs are issues for which the levels of awareness and resources necessary to develop effective solutions have not been sufficiently garnered. Because NTDs are largely confined to poor areas and have relatively low mortality rates, the policy makers and financiers of global health campaigns may underestimate or simply not be aware of the magnitude of the problem.

It is for precisely these reasons (that NTDs are chronically debilitating, affect a large number of indigent people, and are often overlooked) that it is crucial to increase the amount of education, research, and public outreach devoted to their study and treatment.

Even though NTDs are largely confined to developing countries, there are a number of reasons why addressing NTDs is important to developed countries such as the United States, and to the educational systems therein. The argument for increasing the focus on teaching about NTDs can be distilled into three main points: (i) the sheer magnitude of the impact that NTDs have on global health and interconnected world economies warrants a proportionately significant amount of attention in our classrooms (ii) increased awareness of NTDs in Western countries is crucial because successful NTD research programs and public health campaigns can significantly benefit from leadership, expertise, and funding from those with the greatest resources, and (iii) teaching and learning about NTDs provides a unique opportunity to bridge myriad connections between basic science and other disciplines and to promote civic engagement and critical thinking.

### DISCUSSION

#### The worldwide impact of NTDs

A staggering 1.4 billion people are affected by NTDs worldwide (20). This is nearly 40 times the number of people living with HIV (37 million) and more than six times the annual number of cases of malaria reported in recent years (approximately 216 million) (12, 19). Although schistosomiasis alone is responsible for approximately 200,000

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TABLE I.  
Estimated number of cases of neglected tropical diseases (NTDs) worldwide.

Disease	Number of Human Cases	Reference
Buruli ulcer	5,000–6,000 <sup>a</sup>	WHO <sup>20</sup>
Chagas disease	8–11 million <sup>b</sup>	CDC <sup>7</sup>
Dengue	50 million <sup>a</sup>	WHO <sup>20</sup>
Dracunculiasis (Guinea-worm disease)	542 <sup>a</sup>	CDC <sup>7</sup>
Echinococcosis	2–3 million <sup>b</sup>	CFSPH <sup>6</sup>
Foodborne trematodiasis	56 million <sup>b</sup>	WHO <sup>20</sup>
Human African trypanosomiasis (Sleeping sickness)	7,000–10,000 <sup>a</sup>	WHO <sup>20</sup>
Leishmaniasis	0.9–1.6 million <sup>b</sup>	CDC <sup>7</sup>
Leprosy	182,000–219,000 <sup>a</sup>	WHO <sup>20</sup>
Lymphatic filariasis	120 million <sup>b</sup>	WHO <sup>20</sup>
Onchocerciasis (River blindness)	37 million <sup>b</sup>	CDC <sup>7</sup>
Rabies	N/A	
Schistosomiasis	243 million <sup>b</sup>	WHO <sup>20</sup>
Soil transmitted helminthiasis		
Ascaris	807–1,121 million <sup>b</sup>	CDC <sup>7</sup>
Whipworm	604–795 million <sup>b</sup>	CDC <sup>7</sup>
Hookworm	576–740 million <sup>b</sup>	CDC <sup>7</sup>
Taeniasis/Cysticercosis	N/A	
Trachoma	84 million <sup>b</sup>	CDC <sup>7</sup>
Yaws	>80,000 <sup>b</sup>	WHO <sup>20</sup>

<sup>a</sup> Incidence.

<sup>b</sup> Prevalence.

Note: Data are reported for the most recent year available. Prevalence (total number of existing and new cases) is reported for chronic NTDs and incidence (total number of new cases) is reported for acute NTDs or NTDs with a high rate of recurrence.

CDC, Centers for Disease Control; CFSPH, Center for Food Security and Public Health, Iowa State University; N/A, data not available; WHO, World Health Organization.

deaths per year, most NTDs have relatively low mortality rates (20). However, NTDs can be permanently debilitating or disfiguring, and significantly limit the educational opportunities, productivity, and wage earning potential of affected individuals (16). For example, trachoma, the leading cause of preventable blindness in the world, currently impairs the sight of over 8 million people and costs approximately \$2.9 billion in lost productivity each year (7, 16). Even more striking is the Centers for Disease Control (CDC) estimate that the economic benefit of a successful campaign to eliminate lymphatic filariasis could exceed \$55 billion (7). As shown in Table I, these two diseases are far from being the most widespread NTDs, which underscores the immensity of this issue.

The total impact of NTDs is difficult to estimate due to a variety of factors including the chronic nature of these diseases, the confounding effects of multiple comorbidities, and difficulties in accurately tracking and treating diseases in large, diverse, poor populations. The effect of NTDs is perhaps most accurately expressed as the amount of healthy productive years of life lost due to a combination of chronic disability and premature death of affected

individuals. Worldwide, NTDs are responsible for the loss of approximately 46–57 million years of healthy life per annum (16). The only disease that currently causes a greater burden of this type is AIDS (16).

In addition to causing loss of human life and productivity, the pathogens that cause NTDs further devastate poor communities by harming the livestock on which subsistence farmers depend for their livelihood. African trypanosomes, closely related to those that cause human African trypanosomiasis, are responsible for a widespread and devastating disease in livestock called Nagana, which kills three million cattle per year, amounting to a loss of \$4 billion from struggling African economies. Similarly, cysticercosis causes a substantial economic toll by reducing the market value of cattle and pigs, which are rendered unsafe to eat when infected (20).

Because we live in an increasingly interconnected world, the economic and social ramifications of NTDs are not confined to endemic nations; when the health and productivity of one-fifth of the world's population is adversely affected by disease, other nations are indirectly impacted by the moral obligation to provide assistance and the cost of providing

that aid. Some NTDs also impact non-endemic nations more directly. More than 300,000 individuals currently residing in the United States are infected with *Trypanosoma cruzi*, the causative agent of Chagas disease, for which there is no vaccine available (7). Although most of these cases are attributed to infections that occurred outside of the country, at least 31 people have been infected inside the continental United States via vectoral transmission or transfusion of infected blood products (5, 13). And, as recently as 2008, soil-transmitted helminth infections in the United States were estimated at nearly 4 million, occurring mostly in poor regions of Appalachia and the South (10). Even NTDs of which there are few, if any, domestic human cases reported can still exert a great impact on a country. For example, over \$300 million is spent each year in the United States alone to vaccinate animals against rabies in order to prevent human infection (7).

### **The role of the American education system in the fight against NTDs**

The incongruous amount of attention devoted to NTDs compared to other less prevalent diseases, such as AIDS, malaria, and tuberculosis (often referred to as the “big three” diseases), extends beyond the allocation of funding for scientific research and public health campaigns and into the arena of public education. Dr. Peter Hotez, dean of the National School of Tropical Medicine at Baylor College of Medicine, has described NTDs as “the most common diseases you have never heard of,” a characterization that should be actively changed through modifications to our nation’s education system (9). The typical American student enrolled in a general microbiology course is likely to know and learn significantly less about NTDs than HIV/AIDS, even though the incidence of NTDs is much higher. For example, the textbook chosen by this author’s department for use in all microbiology courses, which is a highly regarded text described by the publisher, John Wiley & Sons, Inc., as a best-seller for multiple editions, discusses NTDs on less than 10% of approximately 200 pages devoted to describing infectious diseases. Although the prevalence of a disease is only one of many factors to consider when allocating class time to discussing various pathogens, the striking epidemiology of NTDs, along with the other factors discussed herein, make a strong case for devoting a significant amount of time to the study of these diseases.

The educational merits of teaching about NTDs and the effects of these diseases on American citizens are not the only reasons to teach our students about them. The United States plays a crucial role in the global fight against NTDs, yet our efforts as a nation have been historically inadequate; as of 2012, only 1.3% of the money spent by the United States on global health programs was devoted to NTDs (16). In contrast, malaria and HIV/AIDS (which are much less prevalent) account for 60% of the nation’s global health budget (16). Non-governmental foundations based in the

United States, such as the Gates Foundation, also provide a significant portion of the global budget for combating NTDs; however, there is widespread pressure to tighten budgets and decrease funding of global health programs in both the public and private sector. Equally important to the funding of public health initiatives is the expertise of American scientists and physicians in developing chemotherapeutics that target the causative agents of NTDs, and funding for basic science research has been drastically cut in recent years. Our efforts must be expanded, not stymied, in order to make progress in eradicating NTDs. Increasing awareness of NTDs through education, and promoting the interest of our nation’s students in becoming NTD researchers and health policy-makers, is likely the most promising way to ensure the continuation and redoubling of our nation’s efforts to combat these diseases.

### **NTD education: an opportunity for integrating interdisciplinary learning, civic engagement, and critical thinking into basic science courses**

Due to the tremendously far-reaching and long-lasting impact that NTDs exert on the human race, teaching about these diseases provides a prime opportunity to incorporate interdisciplinary learning and civic engagement into science education. The benefits of interdisciplinary learning, which involves the integration of knowledge from multiple fields of study around a central theme, include helping students access prior knowledge in order to form connections with new knowledge, the promotion of critical thinking and higher-order cognitive skills, improvement of content retention, enhancement of creativity, increased motivation to learn, and increased sensitivity to ethical issues (11, 14). Microbiology lessons about NTDs could easily be paired with an array of courses to facilitate interdisciplinary learning by emphasizing the link between the biology of NTDs and socioeconomic issues. Pairing a microbiology course with a public health course could facilitate interdisciplinary learning by focusing on the development of improved health policies and practices geared towards ameliorating the effects of NTDs in developing nations. Collaboration with epidemiology or mathematics courses could focus on quantifying the impact of NTDs, and utilize real-world NTD-related problems as examples for teaching mathematical concepts. An interdisciplinary approach involving chemistry or pharmacology courses could focus on the development of improved chemotherapeutics to treat NTDs, which is an area of global medicine significantly lacking in funding and progress. Strategies for mobilizing and managing resources to treat and eliminate NTDs and to sever the connection between NTDs and the propagation of poverty could be explored in business, economics, or public policy courses. Because the influence of NTDs on the health and economies of endemic countries has been so forceful and enduring as to shape the histories of those countries, African studies, Asian studies, and Latin

American studies programs would also make appropriate and interesting candidates for interdisciplinary collaborations. The broad implications of NTDs could be further explored in sociology courses by examining the way these diseases have shaped societies over time, and the ethical implications of how those with the resources to make a difference respond to the plight of those in need. All of the aforementioned issues could be further explored by integrating a writing-intensive course in which students can thoroughly develop and communicate their understanding and reactions.

Civic engagement, or the application of knowledge and skills into actions that promote and improve the well being of communities, is becoming increasingly emphasized as an important part of high school and university curricula. As with interdisciplinary learning, the extensive impact NTDs have on communities around the world makes teaching about NTDs well suited to the incorporation of civic engagement. The thought of civic engagement related to NTDs may conjure images of students conducting fieldwork in remote tropical locations, but that is only one way to incorporate civic engagement in the study of NTDs. Because NTDs leave almost no one in the world completely unaffected due to the potential for infection in non-endemic regions, the indirect economic impact that NTDs exert on essentially every nation, and the moral obligation of those with the resources to help, any project that increases awareness of these issues in any community could be a valid civic engagement endeavor. Specific examples of relevant civic engagement projects are described later in this article.

Interdisciplinary learning and civic engagement promote active learning by engaging students in critical thinking, reflective reasoning, data analysis, assessing the validity of data sources, synthesizing ideas and solutions, and interpreting knowledge with cultural literacy. Active learning, in turn, helps propel students through the levels of Bloom's Taxonomy of learning (2), from knowledge acquisition to applying, analyzing, and evaluating scientific information to synthesize solutions to problems.

### Resources for teaching and learning about NTDs

There are a number of pedagogical tools available to facilitate teaching and learning about NTDs. In addition to the material about NTDs presented in textbooks, an array of materials that can be used to supplement instruction is freely available. The Global Health division of the CDC maintains an easily navigable encyclopedic resource about NTDs on its website (<http://www.cdc.gov/globalhealth/ntd/>), providing information about the biology, disease signs and symptoms, diagnostic and treatment options, epidemiology and risk factors, and prevention and control measures for each disease. The scope and presentation of this material makes it a felicitous resource for engaging students in research and active learning. The WHO provides a similar collection of information about NTDs on its website ([http://www.who.int/neglected\\_diseases/diseases/en/](http://www.who.int/neglected_diseases/diseases/en/)), including a

cache of interesting facts about each NTD that are not all easily found on the CDC website; however, the organization and presentation of information by the WHO is less accessible than on the CDC website, making it better suited as a secondary, complementary resource.

Additional resources include: Alliance for Case Studies for Global Health (<http://www.casestudiesforglobalhealth.org>), Global Network for Neglected Tropical Diseases (<http://www.globalnetwork.org>), Pan American Health Organization (<http://new.paho.org>), End Neglected Tropical Diseases in Africa (END in Africa) (<http://endinafrica.org/>), The Neglected Tropical Disease Nongovernmental Development Organizations Network (<http://ntd-ngdonetwork.org/>), and The United States Agency for International Development NTD Program (<http://www.neglecteddiseases.gov/>). These websites may be useful for promoting interdisciplinary discussion and critical thinking because they provide a wealth of information about current and planned public health initiatives, as well as facts, anecdotes, and photographs that illustrate the human toll and vast socioeconomic implications of these diseases. Some courses may benefit from the analysis and discussion of primary literature, a plethora of which is available via National Center for Biotechnology Information (15). The scholarly journal PLOS Neglected Tropical Diseases is devoted exclusively to NTDs, and many other scientific journals regularly publish primary research, review articles, and commentaries about NTDs.

The National Center for Case Study Teaching in Science (NCCSTS) at the University of Buffalo maintains a database of peer-viewed case studies that are freely available for use in the classroom. The NCCSTS database is continually being expanded, and currently includes at least five case studies about NTDs, one on African trypanosomiasis (3), two about Chagas disease (4, 18) and two on Dengue fever (1, 17). These cases are presented as multipart narratives interrupted by questions and active learning exercises. For instructor use only, a password-protected answer key is provided, along with a set of teaching notes describing how the authors implemented the case in their own classroom and tips they have for other instructors who wish to use the case. Many pedagogical tools are utilized in the case studies, including small and large group discussions, brainstorming, problem-based learning, and group presentations that incorporate a research component and peer feedback. To complete the case studies, students analyze scientific data and contextual information to identify a particular NTD-causing pathogen, and evaluate existing public health campaigns in order to synthesize their own plan for effectively treating and preventing the spread of that disease. These case studies provide a framework for examining the interdisciplinary connection of microbiology with fields such as economics, epidemiology, public health, and sociology, and promote civic engagement by emphasizing



the connection between biology and the complex real-world problems facing communities affected by NTDs.

To promote hands-on civic engagement, there are a number of established programs available for educators who have the opportunity to incorporate a study-abroad component into their curriculum. Two programs specifically designed to engage undergraduate students in laboratory and field-based research and community outreach projects in areas that are endemic for NTDs are the Public Health Brigades, overseen by the Global Brigades Association headquartered in Seattle, Washington, and the Tropical Disease Research Program directed by Dr. Mario J. Grijalva at Ohio University. Both of these programs are open to qualified students at colleges around the country and are primarily associated with public health projects related to Chagas disease. The Public Health Brigades program involves a week-long excursion in rural Honduras, where students directly engage with locals in home infrastructural development, community leader training, and health education programs (8). The Tropical Disease Research Program engages students in hands-on modules involving field studies, laboratory research, and healthy living development projects in rural Ecuador over a period of two to six weeks (19). Many other opportunities for qualified students to conduct research and fieldwork exist, but due to variability in the availability and specifications of these programs they will not be described here. To reiterate, relevant civic engagement projects need not involve a travel-abroad component as long as they increase the awareness of the risks, social issues, or need for funding associated with NTDs.

## CONCLUSION

NTDs are often marginalized in the spheres of global health policy and scientific research, as well as in the classroom. There is a strong argument for restructuring microbiology curriculum to increase the emphasis on teaching and learning about NTDs due to the fact that these diseases affect more people worldwide than almost any other group of diseases and because educating students about the seriousness of NTDs is integral to ensuring that the future leaders of the world will focus sufficient resources on ameliorating the global plight caused by this group of diseases. NTDs also provide an opportunity to teach and learn about a diverse and interesting group of organisms, while promoting interdisciplinary learning, civic engagement, and critical thinking. To promote the teaching of NTDs, educators have an array of educational tools to choose from, including informational websites, a case study database, and inter-institutional study-abroad programs.

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